Research Article

Development of a Dimensional Analysis Approach in Gunshot Residue Images Using Computerized Image Processing

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Abstract

Computer image processing is a method that uses artificial intelligence and machine learning-based general learning algorithms. With this method, objects in digital images (photos or videos) can be grouped by being perceived and detected. Computerized image processing method can be applied to almost all kinds of digital data produced with the developing technology. Nowadays, the identification and detection of gunshot residues (GSR) can be done manually by experts from the acquired images. In this study, computerized image processing method was used for the identification and dimensional analysis of gunshot residues (GSR). In this new proposed method, a dataset of 18500 digital image samples obtained from three different caliber cartridges (MKE, Gecco and S&B brands) was used. From the results of the study, it has been shown that the Computer Vision Method is a successful method in the automatic dimensional classification of GSRs.

Keywords: *Computer image processing, Computer vision, Digital forensics, Gunshot residue*

1. Introduction

Computer Vision, or computer image processing, is the field of computer science that enables computers to identify and process objects in the same way that humans can identify and process objects [1]. The computerized image processing method basically covers the subjects such as understanding the obtained image, analyzing it by processing, and extracting numerical data from the images [2]. Images that can be processed in Computer Vision method; It can be in various fields such as photographs, videos, videos taken from multiple cameras looking at the same point, images taken by medical imaging devices, digital forensic images [3]. The first studies on this method was begun in the 1950s. With the development of the Internet, the acquisition of new data sets and the accessibility of data sets have increased the interest in the Computer Vision method. Today, especially face recognition programs are being developed based on Computer Vision method [4].

With the development of technology, computer-based approaches have started to be used especially in the examination of forensic digital evidence. Although forensic experts use computer-based approaches developed in the analysis of forensic digital evidence, they usually make decisions using manual analysis [5]. This situation creates the possibility of human error in the decision-making mechanism. To overcome this problem, computer-based approaches have shown promise.

GSR particles have a special morphological structure (usually spherical and 0-100 micrometers in diameter (in some cases larger) [6]. As a result of the studies conducted in the literature, it has been observed that the morphological structure of GSR particles is formed by the effect of equilibrium-surface distributions. It has been suggested that the morphological dimensional classification of GSR particles is not associated with the equilibrium-surface distribution. Images obtained using SEM (Scanning Electron Microscope) are used in GSR analysis. These images are manually analyzed by forensic experts [7]. Experts make decisions by examining the morphological structure, chemical composition and size of GSR particles from SEM images. This analysis process is challenging and time consuming due to the amount and complexity of digital images.

Therefore, in this study, Computer Vision method is used for automatic dimensional classification of GSRs. This new method is important in terms of reducing the workload of forensic experts and can be used in the dimensional analysis of GSR particles formed according to cartridge brands. In the scope of the study, a dataset covering 18500 samples obtained from three different caliber cartridges (MKE, Gecco and S&B brands) was used. In addition, this data set was shared without any commercial concerns. Access link: http://ilkerkara.karatekin.edu.tr/RequestDataset.html

2. Related Work

There are many studies in the literature about analyzing the morphological structure of GSRs. In this section, studies on dimensional analysis are briefly reviewed.

It was seen that the morphological structures of GSRs were generally spherical as a result of random distribution [8]. In the study by Vermeij et al., it was argued that the morphological structures of GSR particles can be formed in different structures other than spherical structures [9]. Similarly, Kara et al. analyzed the morphological structures of GSR particles. The images obtained by SEM/EDS method were manually analyzed and they suggested that GSR particles consist of 7 different morphological groups [10].

It is important to determine the dimensional distribution of GSR particles. Determining the morphological structure distribution of GSR particles will benefit forensic experts, especially in SEM image analysis. Bruno Cardinetti et al., emphasized that the morphological structures of GSR particles have characteristic features and these features are used in GSR detection investigations [11].

The results presented in [12] for the dimensional distributions of the morphological structures of GSR particles in the literature are remarkable. It is obvious that the idea that the dimensional distribution of the morphological structures of GSR particles is not a random distribution will be useful in the analysis of forensic experts. In their study, Kara et al. manually calculated the data using the Boltzmann method to determine the dimensional distribution of the morphological structures of GSR particles [13]. This situation has triggered the search for new techniques that can automatically determine the morphological structure and dimensional distribution of GSR particles using different techniques.

3. Materials and Methods

In this section, the workflow and system of the proposed analysis approach are described in detail. First, the dataset is introduced and the acquisition of particle images of GSRs is explained. Then, based on the images of GSRs, the dimensional analysis of morphological structures using Computer Vision will be explained.

3.1. Collecting GSR samples and obtaining images

In the literature, a data set obtained by the SEM method of GSR and at standards suitable for the study was not found. For this purpose, a data set that is suitable for the scope of the study was created. MKE, Geco and S&B brand cartridges were used in the study. For this purpose, after the shooter fired three shots into the water tank, double-sided carbon adhesive tape (SPI supplies) was collected from both hands with the swap method and images were obtained in the SEM microscope. Hitachi Su5000 Field Emission Scanning Electron Microscope (FE-SEM) was used for SEM analysis. 18500 SEM image samples were obtained from three different brands used in the study.

3.2. Dimensional analysis of GSR images with Computer Vision

Images obtained by SEM method are widely used in the analysis of GSR particles. Therefore, SEM images were used in the dimensional analysis of GSR particles. For this purpose, dimensional analysis of GSR particles was performed using Computer Vision method (Figure 1). The data set images obtained for this purpose were processed by Computer Vision method.

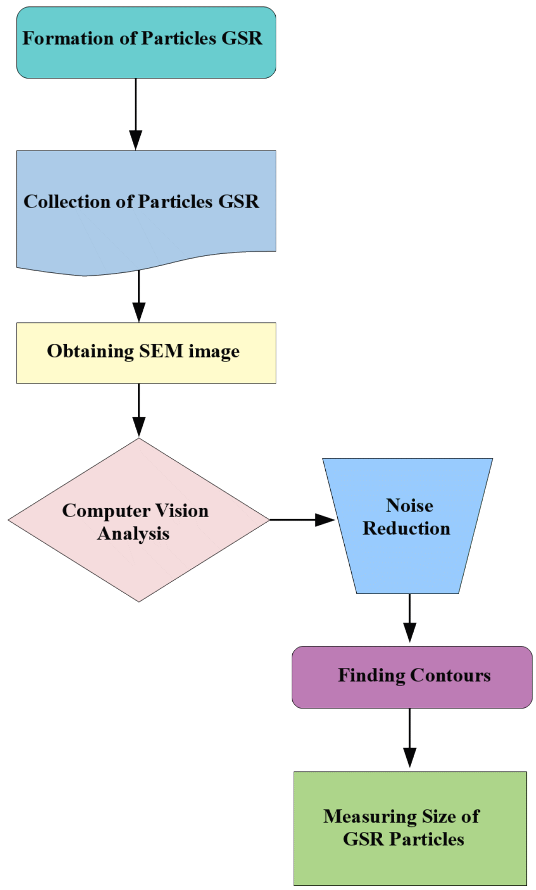

Figure 1: The overall workflow of the proposed approach's

The SEM images in the dataset were analyzed in 8-bit grayscale. Grayscale images do not show color, only the intensity of light. Each pixel is stored in computers as an 8-bit binary code. In other words, if the images are shown as 2^8=256, they take values between 0-255 (where 0 indicates black color and 255 indicates white color).

As can be seen in Figure 1, Computer Vision processing of digitized GSR images consists of 3 steps. The images in the dataset contain some noise, blemishes and unwanted distortions. Therefore, in the first step of the analysis phase, these noise, blemishes and unwanted distortions were removed. For this purpose, the Gausion filter, threshold, erode and dilate functions were used to remove the noise, blemishes and distortions in the image [14].

In the second step, the contours of the GSR were then found in the images. For this, the find contours function from the open-cv library was used for Computer Vision analysis. In step 3, the GSRs were digitized by dimensional analysis of the particles. The x,y coordinates of each GSR particle image are known [15]. The two most distant points between these coordinates are determined. For this, the dist function in the python programming language was used [16].

In addition, the number of pixels in width and height of the SEM images and the MICRON MARKER of the SEM microscope used are known. GSR images take up as much space as the MICRON MARKER size in 152 pixels [15, 16]. In this way, it is possible to calculate how many micro meters 1 pixel is. Using this approach, the morphological structures of all GSR particles in the dataset were digitized by dimensionally calculating their morphological structures from the images (See Figure 2).

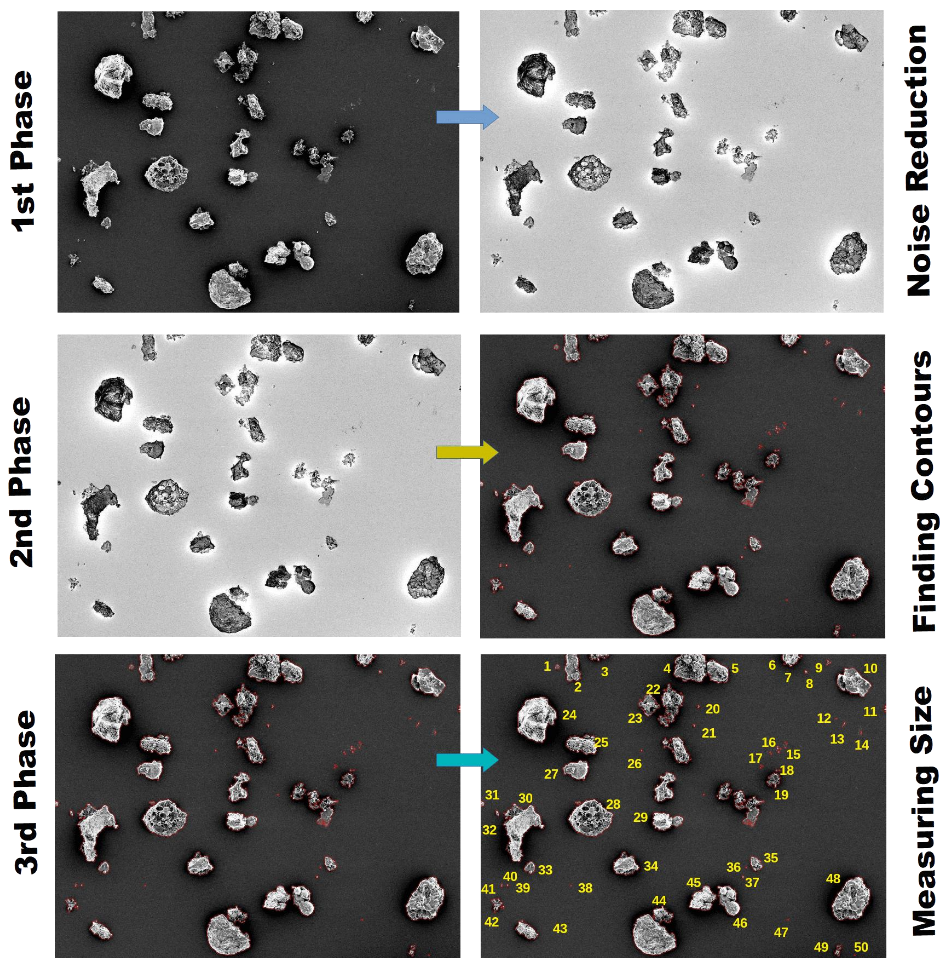

Figure 2: Automatic calculation of the dimensional characteristics of GSR particles using the Computer Vision Method.

The dimensional properties of SEM images of GSR particles obtained using 9 mm diameter MKE, Gecco and S&B cartridges were automatically calculated using the Computer Vision method (Figure 3).

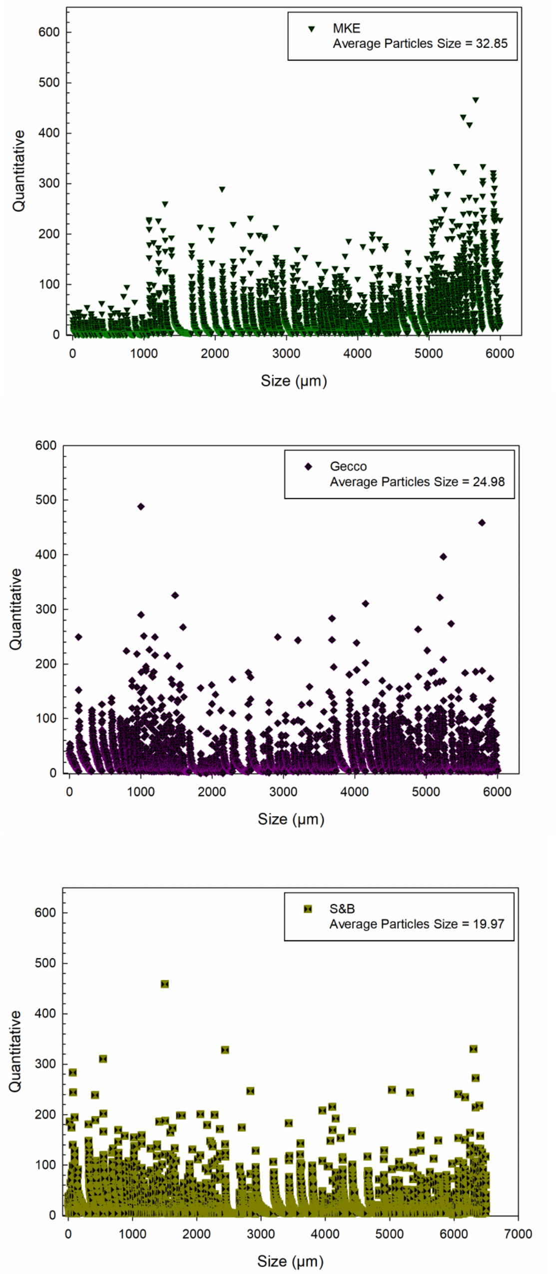

Figure 3: Dimensional distribution analysis of GSR particles using Computer Vision.

4. Results

The classification of GSR particles according to the dimensional analysis of the morphological structures of GSR particles with the Computer Vision method proposed in this study can accelerate the detection process of GSR particles, especially for forensic experts. Specific GSR identification can be utilized in the dimensional calculations of the morphological structures of GSR particles detected according to different brands. However, it should be repeated with different brands and models of cartridges.

However, the dimensional analysis of the morphological structure of GSR particles presents some difficulties. Dimensional analysis of the morphological structure of GSR particles depends on the type of ammunition and environmental conditions (heat, humidity, pollution, etc.). These effects affect the success rate of classification based on dimensional analysis of the morphological structure of GSR particles.

5. Discussion and Conclusion

In this study, a new computer vision based method for dimensional analysis of the morphological structure of GSR particles is proposed. The results of the study showed that the dimensional analysis of GSR particle morphological structures can be performed automatically with the Computer Vision method. These results need to be supported with datasets obtained from different brands and models of cartridges.

In addition, the dimensional analysis of the morphological structures obtained by processing the digital images of GSR particles with Computer Vision has the potential to use deep learning methods. The dataset used in this study is publicly available without any commercial concerns and can be accessed for further research at http://ilkerkara.karatekin.edu.tr/RequestDataset.html.

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